
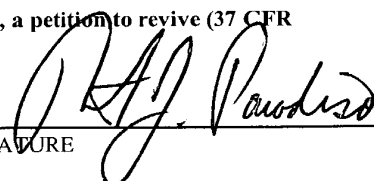


FORM PTO-1390 (Modified) (REV 11-2000)		U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE		ATTORNEY'S DOCKET NUMBER <b>510.1035</b>	
TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371				U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR <b>10/089713</b>	
INTERNATIONAL APPLICATION NO. <b>PCT/EP00/09477</b>		INTERNATIONAL FILING DATE <b>28 September 2000</b>		PRIORITY DATE CLAIMED <b>2 October 1999</b>	
TITLE OF INVENTION <b>AUTOTHERMIC REFORMING REACTOR</b>					
APPLICANT(S) FOR DO/EO/US <b>Andreas DOCTER et al.</b>					
Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:					
<ol style="list-style-type: none"> <li>1. <input checked="" type="checkbox"/> This is a <b>FIRST</b> submission of items concerning a filing under 35 U.S.C. 371.</li> <li>2. <input type="checkbox"/> This is a <b>SECOND</b> or <b>SUBSEQUENT</b> submission of items concerning a filing under 35 U.S.C. 371.</li> <li>3. <input checked="" type="checkbox"/> This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include items (5), (6), (9) and (24) indicated below.</li> <li>4. <input checked="" type="checkbox"/> The US has been elected by the expiration of 19 months from the priority date (Article 31).</li> <li>5. <input checked="" type="checkbox"/> A copy of the International Application as filed (35 U.S.C. 371 (c) (2)) <ol style="list-style-type: none"> <li>a. <input checked="" type="checkbox"/> is attached hereto (required only if not communicated by the International Bureau).</li> <li>b. <input checked="" type="checkbox"/> has been communicated by the International Bureau.</li> <li>c. <input type="checkbox"/> is not required, as the application was filed in the United States Receiving Office (RO/US).</li> </ol> </li> <li>6. <input checked="" type="checkbox"/> An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)). <ol style="list-style-type: none"> <li>a. <input checked="" type="checkbox"/> is attached hereto.</li> <li>b. <input type="checkbox"/> has been previously submitted under 35 U.S.C. 154(d)(4).</li> </ol> </li> <li>7. <input checked="" type="checkbox"/> Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371 (c)(3)) <ol style="list-style-type: none"> <li>a. <input type="checkbox"/> are attached hereto (required only if not communicated by the International Bureau).</li> <li>b. <input type="checkbox"/> have been communicated by the International Bureau.</li> <li>c. <input type="checkbox"/> have not been made; however, the time limit for making such amendments has NOT expired.</li> <li>d. <input checked="" type="checkbox"/> have not been made and will not be made.</li> </ol> </li> <li>8. <input type="checkbox"/> An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).</li> <li>9. <input checked="" type="checkbox"/> An oath or declaration of the inventor(s) (35 U.S.C. 371 (c)(4)).</li> <li>10. <input type="checkbox"/> An English language translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371 (c)(5)).</li> <li>11. <input type="checkbox"/> A copy of the International Preliminary Examination Report (PCT/IPEA/409).</li> <li>12. <input type="checkbox"/> A copy of the International Search Report (PCT/ISA/210).</li> </ol>					
<b>Items 13 to 20 below concern document(s) or information included:</b>					
<ol style="list-style-type: none"> <li>13. <input checked="" type="checkbox"/> An Information Disclosure Statement under 37 CFR 1.97 and 1.98.</li> <li>14. <input type="checkbox"/> An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.</li> <li>15. <input checked="" type="checkbox"/> A <b>FIRST</b> preliminary amendment.</li> <li>16. <input type="checkbox"/> A <b>SECOND</b> or <b>SUBSEQUENT</b> preliminary amendment.</li> <li>17. <input type="checkbox"/> A substitute specification.</li> <li>18. <input type="checkbox"/> A change of power of attorney and/or address letter.</li> <li>19. <input type="checkbox"/> A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1.821 - 1.825.</li> <li>20. <input type="checkbox"/> A second copy of the published international application under 35 U.S.C. 154(d)(4).</li> <li>21. <input type="checkbox"/> A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).</li> <li>22. <input checked="" type="checkbox"/> Certificate of Mailing by Express Mail</li> <li>23. <input checked="" type="checkbox"/> Other items or information: <ul style="list-style-type: none"> <li>- Drawings (6 sheets)</li> <li>- Letter re: Priority</li> <li>- References cited in IDS</li> <li>- Application Data Sheet (2 pages)</li> </ul> </li> </ol>					

U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR 1.492(a)(1)) <div style="font-size: 24pt; font-weight: bold; margin-top: 5px;">10/089713</div>	INTERNATIONAL APPLICATION NO. <div style="font-weight: bold; margin-top: 5px;">PCT/EP00/09477</div>	ATTORNEY'S DOCKET NUMBER <div style="font-weight: bold; margin-top: 5px;">510.1035</div>			
24. The following fees are submitted: <b>BASIC NATIONAL FEE ( 37 CFR 1.492 (a) (1) - (5)) :</b> <input type="checkbox"/> Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO ..... <b>\$1040.00</b> <input checked="" type="checkbox"/> International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO ..... <b>\$890.00</b> <input type="checkbox"/> International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO ..... <b>\$740.00</b> <input type="checkbox"/> International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4) ..... <b>\$710.00</b> <input type="checkbox"/> International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4) ..... <b>\$100.00</b> <div style="text-align: right; margin-top: 5px;"><b>ENTER APPROPRIATE BASIC FEE AMOUNT =</b></div>		<b>CALCULATIONS PTO USE ONLY</b>  <div style="border: 1px solid black; height: 100px; width: 100%;"></div>			
Surcharge of <b>\$130.00</b> for furnishing the oath or declaration later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492 (e)).		<div style="border: 1px solid black; padding: 2px;"><b>\$890.00</b></div> <div style="border: 1px solid black; padding: 2px;"><b>\$0.00</b></div>			
CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	10 - 20 =	0	x \$18.00		<b>\$0.00</b>
Independent claims	1 - 3 =	0	x \$84.00		<b>\$0.00</b>
Multiple Dependent Claims (check if applicable).				<input type="checkbox"/>	<b>\$0.00</b>
<b>TOTAL OF ABOVE CALCULATIONS =</b>					<b>\$890.00</b>
<input type="checkbox"/> Applicant claims small entity status. See 37 CFR 1.27). The fees indicated above are reduced by 1/2.					<b>\$0.00</b>
<b>SUBTOTAL =</b>					<b>\$890.00</b>
Processing fee of <b>\$130.00</b> for furnishing the English translation later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492 (f)).					<b>\$0.00</b>
<b>TOTAL NATIONAL FEE =</b>					<b>\$890.00</b>
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31) (check if applicable).					<b>\$0.00</b>
<b>TOTAL FEES ENCLOSED =</b>					<b>\$890.00</b>
					Amount to be: refunded \$
					charged \$
a. <input checked="" type="checkbox"/> A check in the amount of <b>\$890.00</b> to cover the above fees is enclosed. b. <input type="checkbox"/> Please charge my Deposit Account No. _____ in the amount of _____ to cover the above fees. A duplicate copy of this sheet is enclosed. c. <input checked="" type="checkbox"/> The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. <b>50-0552</b> A duplicate copy of this sheet is enclosed. d. <input type="checkbox"/> Fees are to be charged to a credit card. <b>WARNING:</b> Information on this form may become public. <b>Credit card information should not be included on this form.</b> Provide credit card information and authorization on PTO-2038.					
NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.					
SEND ALL CORRESPONDENCE TO:					
William C. Gehris Davidson, Davidson & Kappel, LLC 485 Seventh Avenue, 14th Floor New York, New York 10018 United States of America					
<div style="display: flex; justify-content: space-between;"> <div style="width: 45%;">   <div style="font-size: 24pt; font-weight: bold; margin-top: 5px;">23280</div> <div style="font-size: 8pt; margin-top: 5px;">PATENT TRADEMARK OFFICE</div> </div> <div style="width: 50%;"> <div style="text-align: right; margin-bottom: 20px;">             SIGNATURE  <b>Robert J. Paradiso</b>            NAME  <b>41,240</b>            REGISTRATION NUMBER  <b>April 1, 2002</b>            DATE         </div> </div> </div>					

510.1035

**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

Re: Application of: DOCTER et al.  
Serial No.: To Be Assigned  
International  
Application No.: PCT/EP00/09477  
Filed: Herewith  
For: AUTOTHERMIC REFORMING REACTOR

BOX PCT  
Asst. Commissioner for Patents  
Washington, D.C. 20231

April 1, 2002

**PRELIMINARY AMENDMENT**

Sir:

Applicants request amendment of the above-identified application prior to a first examination on the merits, as follows:

**IN THE SPECIFICATION:**

Before paragraph [0001], insert the heading --BACKGROUND OF THE INVENTION--.

Replace paragraph [0001] with the following:

[0001] The present invention relates to an autothermic reforming reactor.

Replace paragraph [0005] with the following:

[0005] German Patent Application DE 197 11 044 A1 describes a reactor for sewage sludge incineration. It is aligned vertically, the combustion zone for incinerating the sewage sludge

being situated in the lower region, and the combustion gases, which rise within the reactor, being used for drying the sewage sludge, which enters the reactor from above. Located between the drying zone and the combustion zone is a solid-state radiator having radially arranged, inclined blades similar to a fan wheel. The blades are inclined by 30° to the flow direction of the combustion gases. When passing through the solid-state radiator, the combustion gases give off part of their heat to the solid-state radiator. A part of the absorbed energy is reflected back into the combustion zone as solid-state radiation.

Before paragraph [0006], insert the heading --SUMMARY OF THE INVENTION--.

Replace paragraph [0006] as follows:

[0006] An object of the present invention is to optimize the temperature distribution in the autothermic reactor in such a manner that the reaction zones are thermally decoupled from the quench zone in the best possible manner. A cool down in the rear region of the endothermic zone should be prevented; however, as good as possible an energy feedback into the upstream endothermic zone should be achieved. In this context, the arising loss of pressure of the gas volume flow should be as low as possible.

Delete paragraph [0008].

Before paragraph [0019], insert the heading --BRIEF DESCRIPTION OF THE DRAWINGS--.

Before paragraph [0021], insert the heading --DETAILED DESCRIPTION--.

**IN THE CLAIMS:**

Please cancel claims 1 to 9 without prejudice and add new claims 10 to 19, as follows:

10. (New) An autothermic reforming reactor, comprising:
- an endothermic reaction zone in which a catalyst is provided for endothermic reforming of a raw fuel;
  - an exothermic reaction zone in which energy required for the endothermic reforming reaction is released by an exothermic reaction;
  - a quench zone arranged downstream of the two reaction zones with respect to a direction of a reaction gas volume flow, the reaction gas volume flow being cooled in the quench zone by a liquid; and
  - a gas-permeable heat shield separating the endothermic reaction zone and the quench zone, the heat shield including a thermal insulator for thermally insulating the endothermic reaction zone and the quench zone and a thermal radiator facing the endothermic reaction zone for radiating thermal energy absorbed from the reactor gas volume flow back into the endothermic reaction zone.
11. (New) The autothermic reforming reactor as recited in claim 10 wherein the heat shield further includes an evaporation structure on a side facing the quench zone.
12. (New) The autothermic reforming reactor as recited in claim 11 wherein the heat shield includes a metal foam.
13. (New) The autothermic reforming reactor as recited in claim 10 wherein the exothermic reaction zone is arranged upstream of the endothermic reaction zone.
14. (New) The autothermic reforming reactor as recited in claim 10 wherein the exothermic reaction zone is superimposed over the endothermic reaction zone.

15. (New) The autothermic reforming reactor as recited in claim 10 wherein the heat shield includes flow channels having walls formed by the thermal radiator.
16. (New) The autothermic reforming reactor as recited in claim 10 wherein at least one of the thermal radiator and the thermal insulation includes a cross-channel structure, wire grating structure or perforated plate.
17. (New) The autothermic reforming reactor as recited in claim 10 wherein the thermal radiator includes a foamed structure of metal or ceramics or of a metal/ceramic compound.
18. (New) The autothermic reforming reactor as recited in claim 10 wherein the thermal insulation includes a foamed ceramic structure.
19. (New) The autothermic reforming reactor as recited in claim 10 wherein at least one of the thermal radiator and the thermal insulation includes gap structures in a form of concentric ring gaps or honeycomb structures.

**REMARKS**

Consideration of this application, as amended, is respectfully requested.

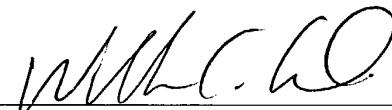
By virtue of this amendment, changes to the specification and new claims have been submitted in order to conform the international application, of which this application is a national stage application, to proper U.S. Patent and Trademark Office practice.

No new matter has been added. Applicants believe that no fees are due as a result of this amendment. In the event of a fee discrepancy, please charge our Deposit Account No. 50-0552.

Respectfully submitted,

DAVIDSON, DAVIDSON & KAPPEL, LLC

By: \_\_\_\_\_



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(212) 736-1940

Application of: DOCTER et al.  
Serial No.: To Be Assigned  
International Application No.: PCT/EP00/09477

VERSION SHOWING CHANGES TO THE SPECIFICATION

[0001] The present invention relates to an autothermic reforming reactor [according to the definition of the species in Patent Claim 1].

[0005] German Patent Application DE 197 11 044 A1 describes a reactor for sewage sludge incineration. It is aligned vertically, the combustion zone for incinerating the sewage sludge being situated in the lower region, and the combustion gases, which rise within the reactor, being used for drying the sewage sludge, which enters the reactor from above. Located between the drying zone and the combustion zone is a solid-state radiator having radially arranged, inclined blades similar to a fan wheel. The blades are inclined by 30°[C] to the flow direction of the combustion gases. When passing through the solid-state radiator, the combustion gases give off part of their heat to the solid-state radiator. A part of the absorbed energy is reflected back into the combustion zone as solid-state radiation.

[0006] [The] An object of the present invention is to optimize the temperature distribution in the autothermic reactor in such a manner that the reaction zones are thermally decoupled from the quench zone in the best possible manner. A cool down in the rear region of the endothermic zone should be prevented; however, as good as possible an energy feedback into the upstream endothermic zone should be achieved. In this context, the arising loss of pressure of the gas volume flow should be as low as possible.





Rec'd POT/PTO 05 AUG 2002

[510.1035]

10/089713

Specification

AUTOTHERMIC REFORMING REACTOR

[0001] The present invention relates to an autothermic reforming reactor according to the definition of the species in Patent Claim 1.

[0002] During the operation of fuel cells having polymer membranes, briefly called PEM fuel cells, in particular for mobile applications, it is possible to produce a hydrogen-rich gas from a liquid raw fuel by reforming liquid hydrocarbons, for example, gasoline or Diesel fuel.

[0003] This reaction can advantageously be carried out in an autothermic reactor. There inside, energy is released by an exothermic combustion which is used for heating the endothermic reforming reaction. In the ideal case, the exothermic reaction zone is superimposed over the endothermic reaction zone. However, it is also possible for the exothermic reaction to be arranged upstream of the endothermic reaction. In the endothermic reaction zone, the charged water/air/hydrocarbon mixture is converted to an H<sub>2</sub>-rich gas which also contains CO in addition to CO<sub>2</sub>. To prevent the CO gas in the gas mixture from reacting back to elemental carbon (soot) at the end of the reactor, it is required for the gas mixture to be quickly cooled down to a low temperature level. This is achieved by adding water and is referred to as quenching. For the case of the partial oxidation of hydrocarbons, this process is described, for example, in US Patent 5,358,696 or in US Patent 2,664,402.

[0004] Due to the quenching process, a temperature gradient which corresponds to the cool down arises in the reactor. This is undesirable because the accompanying heat loss produces too low a temperature in the rear region of the endothermic zone. This temperature is decisive for the gas composition since the thermodynamic equilibrium of the reforming reaction is temperature dependent.

[0005] German Patent Application DE 197 11 044 A1 describes a reactor for sewage sludge incineration. It is aligned vertically, the combustion zone for incinerating the sewage sludge being situated in the lower region, and the combustion gases, which rise within the reactor, being used for drying the sewage sludge, which enters the reactor from above.

Located between the drying zone and the combustion zone is a solid-state radiator having radially arranged, inclined blades similar to a fan wheel. The blades are inclined by 30°C to the flow direction of the combustion gases. When passing through the solid-state radiator, the combustion gases give off part of their heat to the solid-state radiator. A part of the absorbed energy is reflected back into the combustion zone as solid-state radiation.

[0006] The object of the present invention is to optimize the temperature distribution in the autothermic reactor in such a manner that the reaction zones are thermally decoupled from the quench zone in the best possible manner. A cool down in the rear region of the endothermic zone should be prevented; however, as good as possible an energy feedback into the upstream endothermic zone should be achieved. In this context, the arising loss of pressure of the gas volume flow should be as low as possible.

[0007] This objective is achieved by the autothermic reactor according to Patent Claim 1. Advantageous embodiments of the present invention are the subject matter of subclaims.

[0008] According to the present invention, provision is made for a gas-permeable heat shield which is arranged in the reactor gas volume flow between the reaction zones of the reactor and the quench zone. The heat shield essentially includes two components:

- a thermal insulation for thermally insulating the endothermic reaction zone and the quench zone,
- a thermal radiator for radiating the thermal energy absorbed from the effluent reactor gas volume flow. Its surface faces the endothermic reaction zone. The radiant power increases with the fourth power of the surface temperature in accordance with the Stefan-Boltzmann law. The hotter the gas temperature, the hotter is the surface of the heat shield and the higher is the energy radiated in the direction of the endothermic reaction zone.

[0009] Thus, mainly the following heat transfer mechanisms are of importance for the mode of operation of the temperature-stabilized reactor according to the present invention:

- heat transfer from the gas volume flow to the heat shield; here, above all, the convective heat transfer through forced convection is of importance. In this connection, it is advantageous to produce a turbulent flow. This turbulent flow can be achieved by a

suitable geometric design of the heat shield. Moreover, the heat shield geometry can be designed in such a manner that the heat flow to the surface of the thermal radiator is optimized.

- radiant heat transfer from the heat shield back to the reforming catalyst located in the reaction zone. Typical temperatures during the execution of the reforming reaction with gasoline or Diesel fuel lie in the range of about 900°C. At these temperatures, the radiated power is already relatively high. Via the surface type (ideally having the characteristic of a blackbody radiator) as well as the surface quality, it is possible to attain maximum radiation efficiency.

**[0010]** Thus, a very good thermal insulation of the quench zone from the autothermic region of the reactor is achieved using the heat shield according to the present invention. The endothermic reaction zone can be maintained at operating temperature without being influenced by the temperature drop in the quench zone.

**[0011]** At the same time, an energy feedback is attained in that the heat of the gas volume flow which has been absorbed by the heat shield is reflected back into the endothermic zone. Therefore, the heat losses caused by the effluent gas mass flow can be considerably reduced.

**[0012]** Moreover, the heat shield according to the present invention, advantageously acts as an energy store during load changes, as will be explained in the following:

**[0013]** In a reactor, one can essentially distinguish between two types of heat losses:

- wall losses: heat losses to the surroundings through the reactor insulation and via the reactor surface;
- gas volume flow losses: heat losses caused by the effluent gas mass flow and the gas temperature. The gas volume flow losses are dependent on the gas mass flow, the heat-absorption capacity of the flowing gas mixture, and on the temperature gradient.

**[0014]** During load changes, the exothermic energy release varies in proportion to the load change. Since the wall losses depend substantially on the inside temperature but the gas volume flow losses vary in proportion to the load, the proportions of the types of loss shift

accordingly during load change. The lower the load, the higher is the proportion of the wall losses, and the higher the load, the higher is the proportion of the volume flow losses.

[0015] Under the described conditions, the heat shield according to the present invention can be used as a heat buffer for stabilizing the operating temperature of the reactor. During a downward change in load, it releases its previously absorbed energy in a time-delayed manner, depending on its heat-absorption capacity, thus slowing down the cooling. During an upward change in load, the proportionally increasing volume flow loss is reduced through the heat absorption of the heat shield.

[0016] Moreover, a more constant control of the quenching is attained via this damping process. This also permits a more uniform supply to the shift reaction for removing CO arranged downstream of a reactor.

[0017] The reforming catalyst according to the present invention can be used, in particular, for reforming hydrocarbons such as gasoline or Diesel fuel.

[0018] The reforming reactor according to the present invention can be used, in particular, in a fuel-cell powered motor vehicle for supplying the fuel cell with hydrogen.

[0019] The present invention will be explained in greater detail in the light of exemplary embodiments with reference to drawings.

- [0020] Fig. 1 is a schematic representation of a reactor according to the present invention;
- Fig. 2 depicts the radiant power (Watt) of a heat shield according to the present invention as a function of the temperature (°C);
- Fig. 3 is a schematic representation of an embodiment of the heat shield according to the present invention.
- Fig. 4 shows a concrete embodiment of the heat shield according to the present invention;
- Fig. 5,6 depict further concrete embodiments of the heat shield according to the present invention.

[0021] Fig. 1 is a schematic representation of an autothermic reforming reactor according to the present invention. It includes the autothermic reaction zone in which the exothermic reaction for releasing energy as well as the endothermic reforming reaction take place. The charged hydrocarbons as well as air and  $H_2O$  are converted to an  $H_2$ -rich, CO-containing gas mixture therein. Downstream of the autothermic reaction zone is arranged the quench zone in which the gas mixture, upon passage through the gas-permeable heat shield, is quickly cooled down to a low temperature level by adding a liquid, usually water. In this variant, the heat shield according to the present invention is positioned transversely to the flow direction of the gas volume flow. It is advantageously configured in such a manner that it has as large a surface area as possible. The heat shield according to the present invention extends over the entire cross-section of the reactor so that the reactor is structurally divided into two chambers.

[0022] Fig. 1 additionally shows a plot of a temperature distribution inside the reactor along the flow direction. In this context, the broken lines mark the values in a reactor according to the present invention, the solid lines indicate the values in a conventional reactor. It is discernible that in the reactor according to the present invention, there is a marked temperature gradient in the region of the heat shield so that the quench zone is thermally well decoupled from the reaction zones. In contrast, the conventional reactor features a continuous temperature gradient over the entire length of the reactor. Because of this, heat losses occur in the rear region of the reaction zone (as viewed in the direction of flow), involving the disadvantages explained in the introductory description.

[0023] Fig. 2 shows the radiant power of a heat shield according to the present invention for a specific, exemplary diameter. As is discernible in the drawing, the radiant power increases in proportion to the fourth power of the temperature in accordance with the Stefan-Boltzmann law.

[0024] Fig. 3 is a schematic representation of an embodiment of the heat shield according to the present invention. Heat shield HS is arranged in the reactor gas volume flow between the autothermic reaction zone and the quench zone. In this variant, heat shield HS includes the following elements which are arranged side-by-side in a layer-like manner:

- A thermal radiator STR made of a foam of metal or ceramics. It faces the autothermic reaction zone and reflects the heat which has been transferred by convection from the reactor gas volume flow to the heat shield back into the reaction zone.
- Thermal insulation IS made of a thermally insulating pourable ceramic compound or a preformed ceramic part. The thermal insulation can have a foam-like structure.
- An evaporator structure VD made of a metal foam having as large as possible a surface area. It serves to support the quenching of the reactor gas volume flow in that the water which has been added, for example, injected or sprayed in, for cooling is evaporated at its surface as fast as possible.

[0025] Fig. 4 shows a concrete embodiment of heat shield HS according to the present invention. It includes thermal radiator STR whose surface facing the reaction zone serves as radiant surface SF via which the heat which has been transferred from the gas volume flow to heat shield HS is reflected back into the reaction zone as radiant energy. Moreover, there exists a thermal insulation IS.

[0026] Heat shield HS is structurally designed in such a way that as high a radiation as possible is attained in countercurrent direction and that, at the same time, as good as possible a thermal insulation is attained with respect to the quench zone arranged downstream in the direction of flow. For a good heat transfer from the gas volume flow to heat shield HS, it is advantageous to produce a turbulent flow, for example, through a suitable selection of the flow cross-section. In the variant shown, flow channels GK for the reactor gas volume flow have either a conical or a cylindrical shape. The walls of flow channels GK are formed by thermal radiator STR. In this manner, the heat flow to the radiation-active surface SF of thermal radiator STR is optimized. In this variant, thermal insulation IS is thus composed of a plurality of individual unconnected regions.

[0027] Figs. 5 and 6 show further embodiments of heat shield HS according to the present invention. In each case, the thermal radiator is represented as the outermost layer of the heat shield. Each variant is shown both in a top view and in a cross-section. The upper figure, Fig. 5a, depicts a first variant of the thermal radiator as a ceramic or metal foam. Fig. 5b shows a further variant in which the thermal radiator is designed as a cross-channel structure, for

example, according to German Patent Application DE 43 34 981 A1. Finally, Fig. 5c and Fig. 5d show variants made of wire grating structures or perforated plates.

[0028] Fig. 6 depicts variants of heat shield HS according to the present invention, featuring different gap structures as flow channels GK for the gas volume flow. Fig. 6a shows a gap structure composed of a plurality of concentric ring gaps. Fig. 6b shows a honeycomb-like gap structure. In this connection, the “webs” between the “honeycombs” form the gaps whereas the “honeycombs” constitute surface SF of the thermal radiator.

[0029] Particularly suitable materials for heat shield HS are those meeting the following requirements:

- minimum pressure loss,
- maximum surface area, in particular, perpendicularly to the direction of flow,
- temperature resistance,
- resistance to thermal shocks,
- resistance to scaling.

[0030] The latter property is relevant because a breakthrough of O<sub>2</sub> can occur in the case of inhomogeneous mixture formation in the reaction zone.

What is claimed is:

1. An autothermic reforming reactor, comprising
  - an endothermic reaction zone in which the reforming reaction take places;
  - an exothermic reaction zone in which the energy required for the reforming reaction is released;
  - a quench zone arranged downstream of the reaction zones for the rapid cooling of the reactor gas volume flow by adding a liquid;wherein  
the endothermic reaction zone and the quench zone are separated by a gas-permeable heat shield (HS), the heat shield (HS) including
  - a thermal insulation (IS) for thermally insulating the endothermic reaction zone and the quench zone, as well as
  - a thermal radiator (STR) which faces the endothermic reaction zone and is used for radiating, in countercurrent direction, the thermal energy which has been absorbed from the reactor gas volume flow.
2. The autothermic reforming reactor as recited in Claim 1,  
wherein the heat shield (HS) includes an evaporation structure (VD) on its side facing the quench zone, the heat shield being made, for example, of a metal foam.
3. The autothermic reforming reactor as recited in Claim 1 or 2,  
wherein the exothermic reaction zone is arranged upstream of the endothermic reaction zone.
4. The autothermic reforming reactor as recited in one of the Claims 1 or 2,  
wherein the exothermic reaction zone is superimposed over the endothermic reaction zone.
5. The autothermic reforming reactor as recited in one of the preceding Claims,  
wherein the heat shield (HS) features flow channels (GK) whose walls are formed by the thermal radiator (STR).
6. The autothermic reforming reactor as recited in one of the Claims 1 to 4,



wherein the thermal radiator (STR) and/or the thermal insulation (IS) is/are designed as cross-channel structure, wire grating structure or perforated plate.

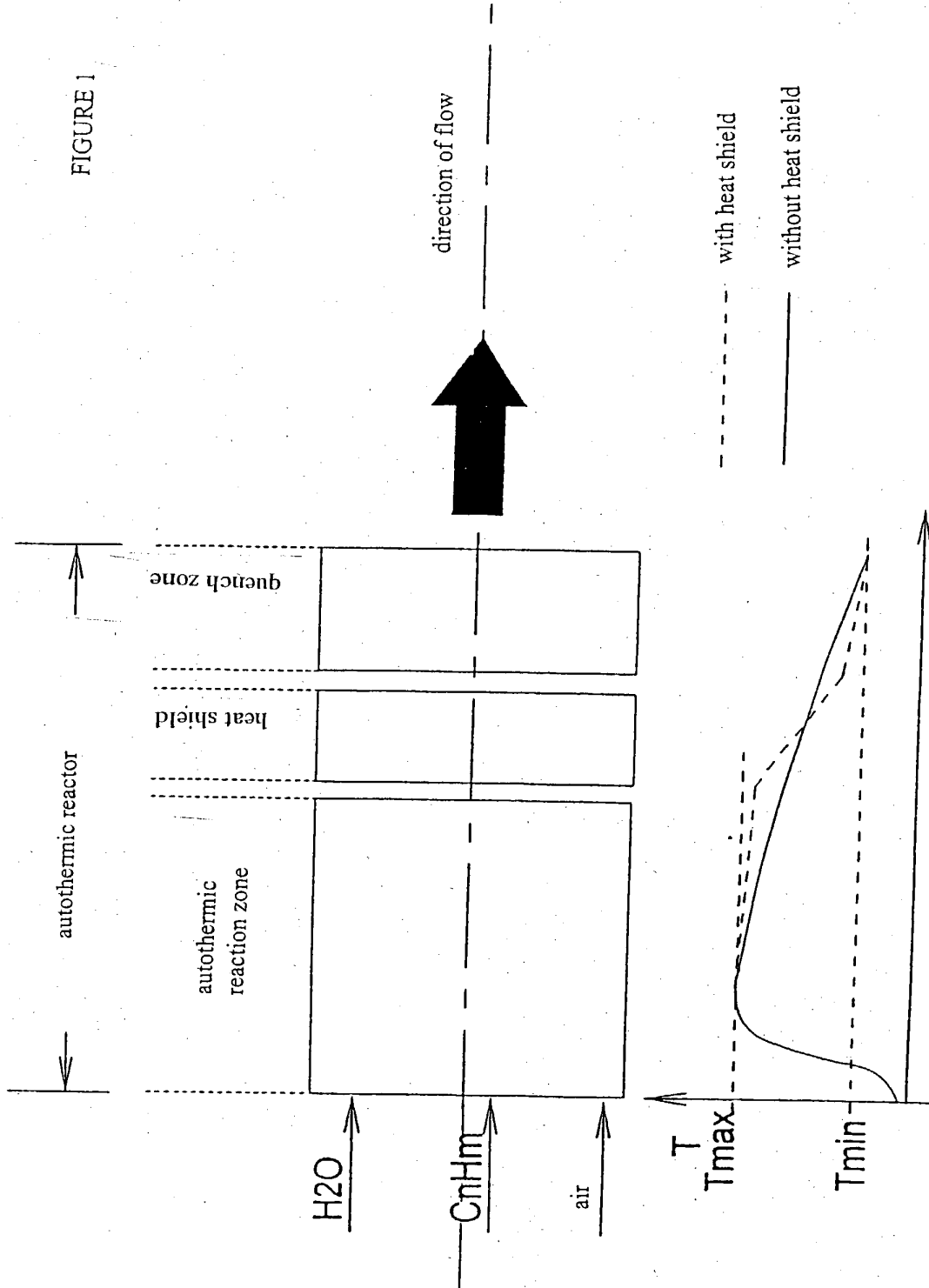
7. The autothermic reforming reactor as recited in one of the Claims 1 to 4, wherein the thermal radiator (STR) is formed as a foam-like structure of metal or ceramics or of a metal/ceramic compound.
8. The autothermic reforming reactor as recited in one of the Claims 1 to 4, wherein the thermal insulation (IS) is formed as a foam-like structure of ceramics.
9. The autothermic reforming reactor as recited in one of the Claims 1 to 4, wherein the thermal radiator (STR) and/or the thermal insulation (IS) features/feature gap structures in the form of concentric ring gaps or in the form of honeycomb structures.

## Abstract

**[0031]** The invention relates to an autothermic reforming reactor, comprising an endothermic reaction zone, in which the reforming reaction takes place; - an exothermic reaction zone, in which the energy is released which is required for the reforming reaction; - a quench zone connected downstream of the reaction zones for the rapid cooling of the reactor gas volume flow. According to the invention, the endothermic reaction zone and the quench zone are separated by a gas permeable heat shield (HS), whereby the heat shield (HS) comprises -thermal insulation (IS) for thermally insulating the endothermic reaction zone and quench zone, in addition to - a thermal radiator (STR) which faces the endothermic reaction zone and radiates the thermal energy which has been absorbed from the reactor gas volume flow.

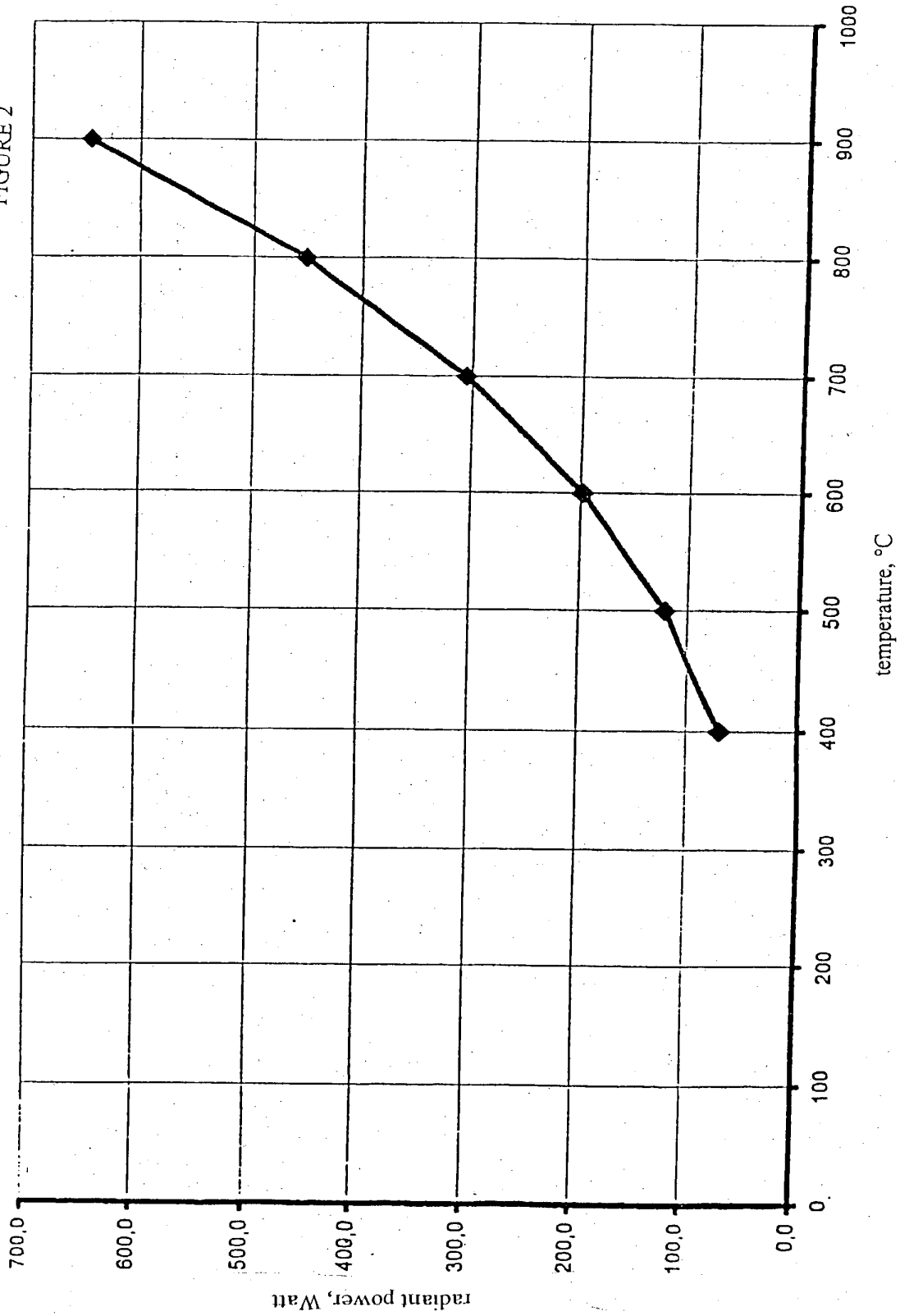
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FIGURE 1



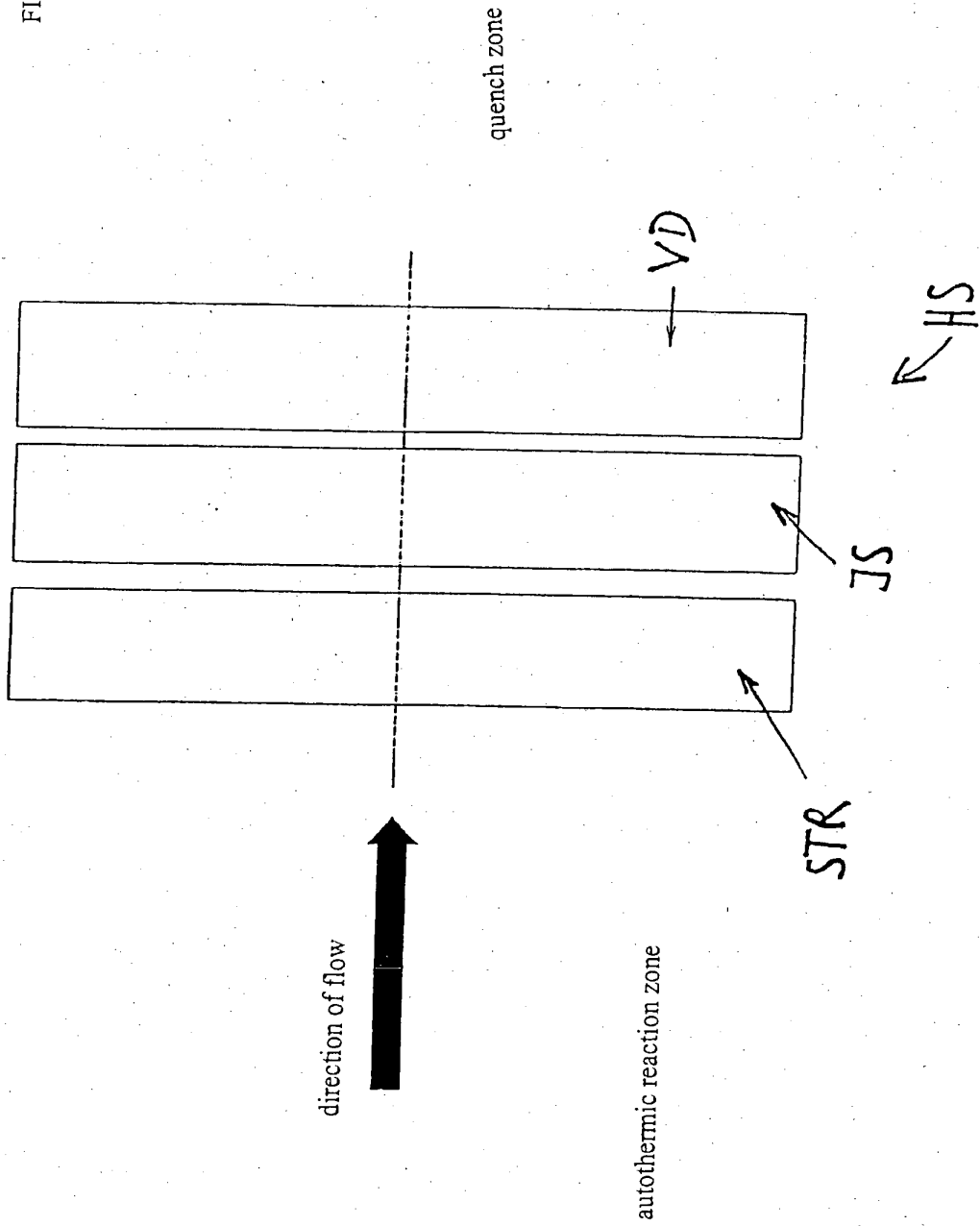
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FIGURE 2



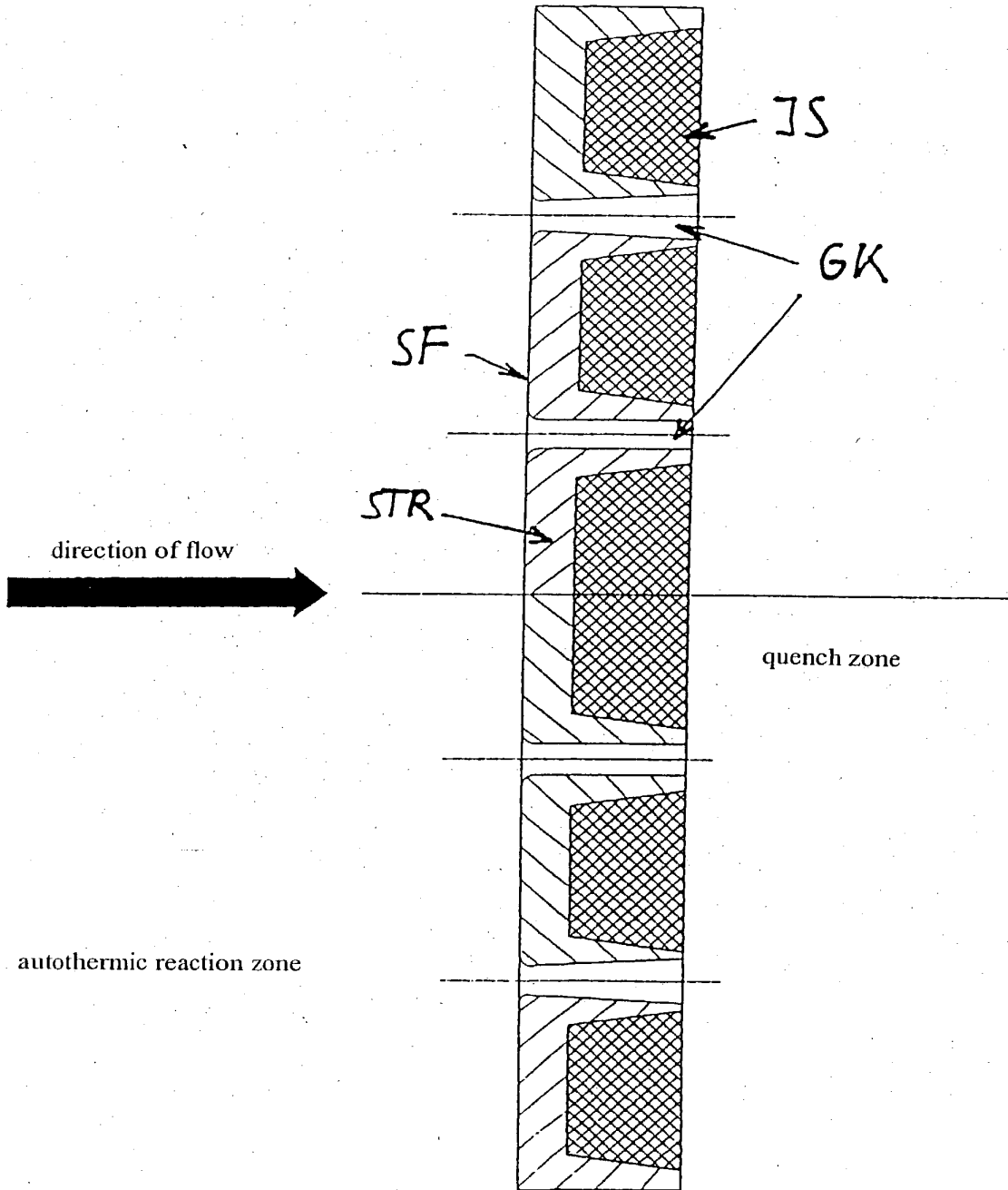
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FIGURE 3



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Fig. 4



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Fig. 5

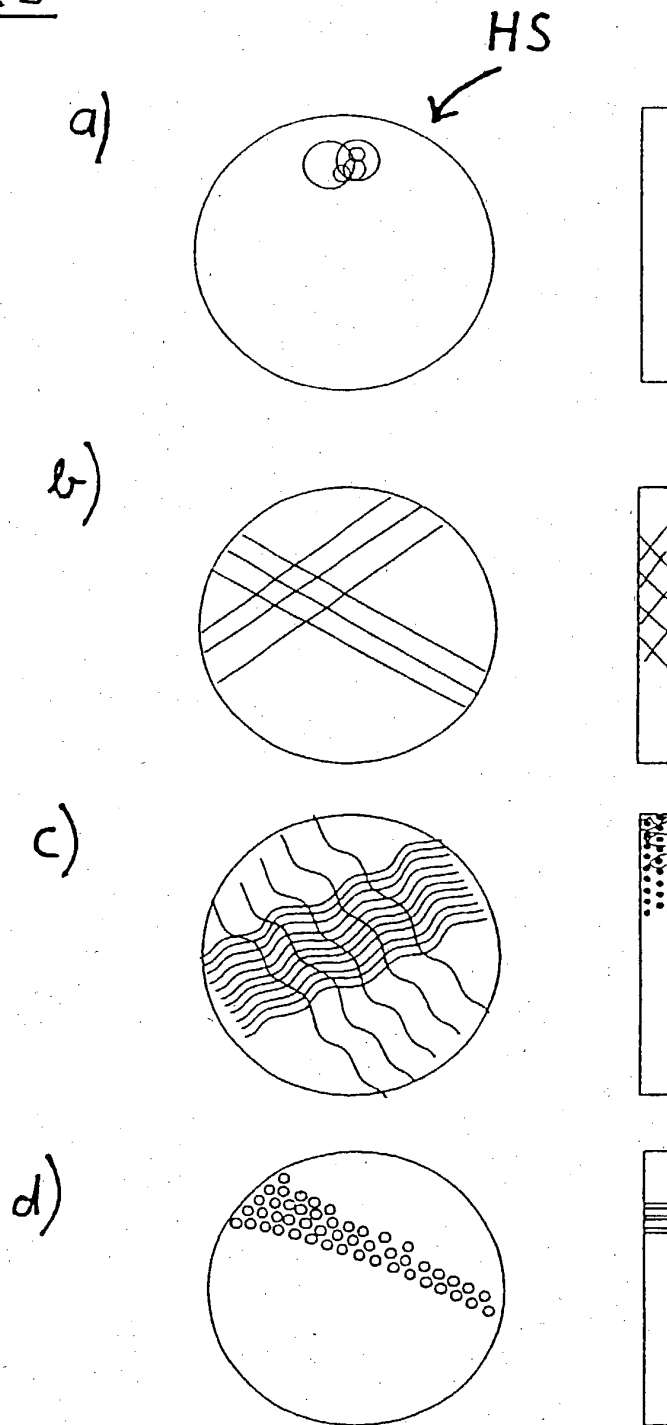
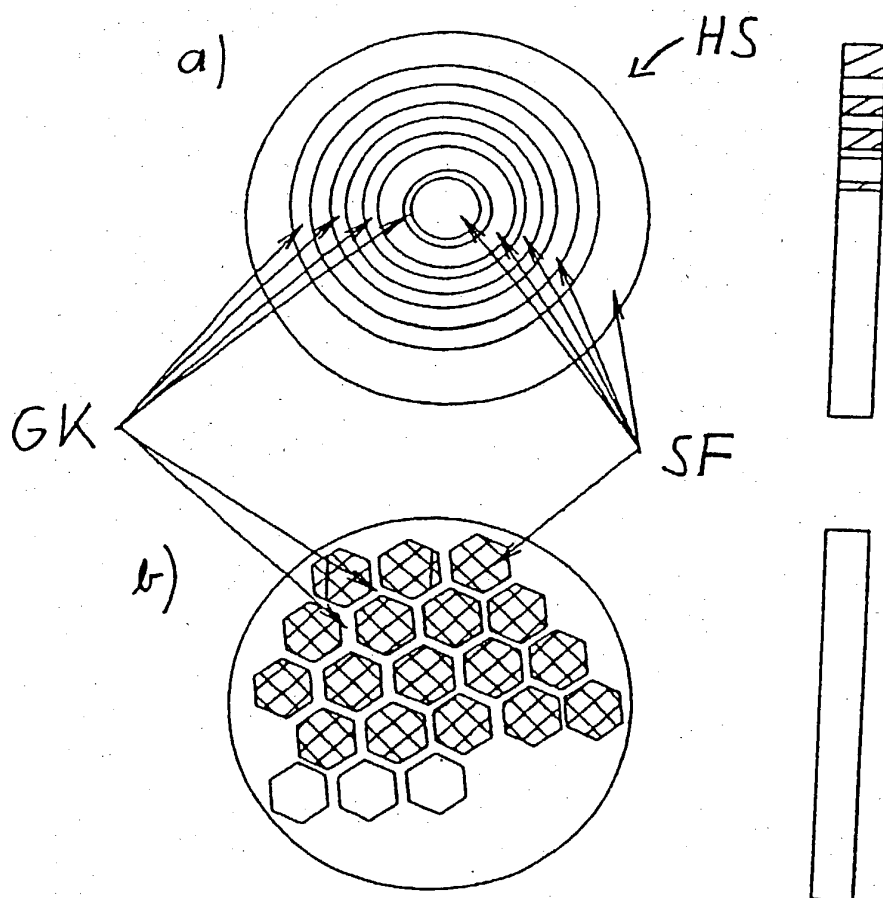
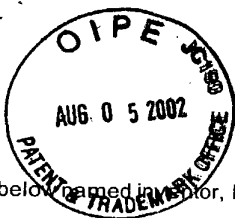


Fig. 6







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## DECLARATION AND POWER OF ATTORNEY

Docket No.: 510.1035

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter that is claimed and for which a patent is sought on the invention entitled:

AUTOTHERMIC REFORMING REACTOR

the specification of which (check one)

☐ is attached hereto

☒ was filed on 28 September 2000 as International Application Serial No. PCT/EP00/09477 and was amended on (if applicable).

☒ I hereby authorize and request our attorneys, Davidson, Davidson & Kappel, LLC of 485 Seventh Avenue, New York, New York 10018 to insert here in parentheses (application number 10/089,713, filed 4/1/2002) the filing date and application number of said application when known.

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose all information that is known to me to be material to the patentability of this application as defined in Title 37, Code of Federal Regulations, §1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign and/or provisional application(s) for patent or inventor's certificate listed below and have also identified below any foreign and/or provisional application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

DE 199 47 755.8	Germany	2 October 1999	Priority claimed <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No
Number	Country	Day/Month/Year Filed	
			Priority claimed <input type="checkbox"/> Yes <input type="checkbox"/> No
Number	Country	Day/Month/Year Filed	

I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

Application Serial Number	Day/Month/Year Filed	Status
Application Serial Number	Day/Month/Year Filed	Status

And I hereby appoint Clifford M. Davidson, Reg. No. 32,728, Leslye B. Davidson, Reg. No. 38,854, Cary S. Kappel, Reg. No. 36,561, William C. Gehris, Reg. No. 38,156, Morey B. Wildes, Reg. No. 36,968, Robert J. Paradiso, Reg. No. 41,240, Erik R. Swanson, Reg. No. 40,833, Thomas P. Canty, Reg. No. 44,586, Livia S. Boyadjian, Reg. No. 34,781, and all other registered attorneys and agents at Davidson, Davidson & Kappel, LLC, U.S. Patent and Trademark Office Customer Number 23280, my attorneys, with full power of substitution and revocation, to prosecute this application and to transact all business in the U.S. Patent and Trademark Office connected therewith; correspondence address: DAVIDSON, DAVIDSON & KAPPEL, LLC, 485 Seventh Avenue, 14th Floor, New York, New York 10018; Telephone: (212) 736-1940; Fax: (212) 736-2427.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Title 18, United States Code, §1001 and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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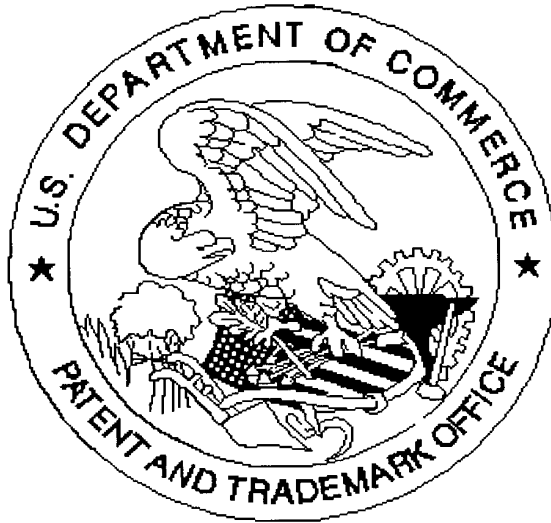
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